Reviews

Documentation of classical biological control introductions

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Abstract In view of increasing world attention to biodiversity and faunal surveys, improved documentation of the movement of biological control agents from one part of the world to another is needed. More detailed record-keeping and retention of voucher specimens can also help improve the success rate and provide useful feedback for classical biological control programs. The availability of such records will also aid research by ecologists and taxonomists and help regulatory agencies prevent the introduction of harmful exotic organisms. One of the functions of the Biological Control Documentation Center of the Agricultural Research Service (ARS) of the US Department of Agriculture (USDA) is to improve the documentation of the introduction of biological control agents into the United States. A computerized system has been developed for making such records more readily available and useful to scientists and other users of these data. The ARS documentation system and the computerized *Releases of Beneficial Organisms in the United States and Territories* (*ROBO*) program and publication series are described. Objections raised to these systems by some US researchers are discussed. The ARS documentation system and ROBO program provide insights into improved methods for documenting the international movement and release of beneficial organisms in other parts of the world.

Keywords Biological control; introduced organisms; documentation; biodiversity; voucher specimens

Introduction

The need for careful documentation of the introduction of exotic natural enemies in classical biological control programs was noted at the very start of such programs in the United States (Smart, 1899, quoted in Howarth, 1991), and the subject of documentation was included in one of the first important biological control textbooks (DeBach and Schlinger, 1964). However, the subject is singularly ignored in most recent books and review articles describing procedures for conducting classical biological control, an example being the excellent review by Wapshere, Delfosse and Cullen (1989) that recently appeared in this journal. The importance of careful documentation of the collection of living organisms in one part of the world and their release in another where they do not occur should be regularly and prominently stressed in biological control procedural papers and books, for example, as in Fisher and Andres (1992). Such documentation is important not only to a biological control program itself, but also because information is provided on the fauna, or potential increase in the known fauna, of both the areas of collection and release, respectively. The latter point has long been of keen interest to taxonomists and ecologists but is particularly important today in view of the increased world interest in biodiversity, faunal and floral inventories or biological surveys, environmental quality and pollution, and, of course, biological pest control. Evidence of this increased interest is shown by the organization of several recent symposia, e.g. by the Association of Systematics Collections (ASC) in 1985 on a US National Biological Survey (Kim and Knutson, 1986) and by the International Union of Biological Sciences (IUBS) in Amsterdam in September 1991 on *Biological Diversity and Global Change*, and by legislation introduced into the US Congress in 1991 concerning biodiversity and cataloguing and conserving organisms in the US (Lancaster, 1991). In addition, two major scientific workshops were held in 1991 in the United States concerning regulations and guidelines for introduction of biological control agents, and international guidelines for movement of such agents are currently being developed by the Food and Agriculture Organization (FAO) of the United Nations. Documentation is an important part of these various guidelines for introduction of natural enemies, particularly in those being promulgated for scientists of the Agricultural Research Service (ARS) of the US Department of Agriculture (USDA) (Coulson and Soper, 1989; Coulson, Soper and Williams, 1991).

The importance of biological surveys and knowledge of biodiversity to systematics, long-range ecological research, environmental protection, plant protection, and food production is aptly described by Kim and Knutson (1986). In this paper, I relate the importance and benefits of documenting the movement of organisms to systematics, ecology, and biological control, describe the formation and

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functions of the ARS Biological Control Documentation Center (BCDC), and discuss some of the methods and problems involved in biological control documentation. Most comments refer to events and situations in the United States, but are also applicable to other countries.

ARS Biological Control Documentation Center

The establishment, functions and programs of the BCDC were described by Coulson (1988). USDA scientists have been engaged in the introduction and release of exotic natural enemies of pests in the United States since the first biological control attempts in the United States in the 1880s. In 1934, administrative responsibility for all USDA overseas biological control laboratories and foreign exploration activities was centralized in the Division of Foreign Parasite Introduction of USDA's Bureau of Entomology and Plant Quarantine. Shortly thereafter, the Division was also made responsible for all of USDA's biological control quarantine facility activities and much of its release and establishment activities involving natural enemies of insects and weeds. The Division was directed by C. P. Clausen until his retirement in 1951, when he became Chairman of the Department of Biological Control of the University of California. The office responsible for the USDA classical biological control programs continued under changed titles, and from 1953 was closely associated with USDA's insect and mite taxonomic unit, the ARS Systematic Entomology Laboratory, under the name Insect Identification and Parasite Introduction Research Branch, or IIPI; P. W. Oman, W. H. Anderson, and R. I. Sailer served as respective leaders of this Branch.

The IIPI and its predecessor Division maintained close communication with the University of California and Hawaii Department of Agriculture, which, until the 1970s, were the only other organizations directly involved in the importation of exotic invertebrate biological control organisms into the United States, i.e. the only ones with approved and active quarantine facilities. These units freely exchanged records and information, published and unpublished, on their respective activities. As a result, Clausen was able to compile and publish an account of classical biological control of insects in the continental United States through 1950 (Clausen, 1956). This account was subsequently augmented by an excellent review of pertinent literature through 1968, broadened in scope to encompass worldwide introduction activities involving natural enemies of both insects and weeds, by University of California scientists under Clausen's overall editorship (Clausen, 1978). The IIPI also published a historical record specifically related to the introduction of natural enemies of forest insects (Dowden, 1962).

The IIPI, and close centralized direction of the ARS classical biological control programs from overseas research to field release and evaluation, was abolished during a reorganization of the ARS in 1972. The voluminous and valuable files of published and unpublished reports, correspondence, reprints, and other documents concerning USDA and various state natural enemy introduction programs, accumulated from 1934 to 1972 by the IIPI and its predecessor Division, and shipment-and-release records accumulated during that period and earlier by Clausen, were placed in the newly created Beneficial Insect Introduction Laboratory (BIIL). The BIIL remained associated with the Systematic Entomology Laboratory in the Insect Identification and Beneficial Insect Introduction Institute (later Biosystematics and Beneficial Insects Institute) at Beltsville; Lloyd Knutson served as Institute Chair from 1973 until the Institute was abolished in 1985. Efforts to maintain and update the files and records were begun by BIIL immediately after the 1972 ARS reorganization. These efforts became increasingly difficult owing to the ever-increasing number of federal, university, and state units, and more recently private concerns, involved in importation and release of exotic natural enemies of pests in the United States.

In 1978, a special federal–state–university study team coordinated by USDA's Office of Environmental Quality published a detailed report on the status of biological pest control in the US (US Department of Agriculture, 1978). One of the report's high-priority recommendations to help strengthen research on biological control was to develop 'a national information storage and coordinating system specifically designed for assembling and collating domestic and international information relevant to all biological agents that might be used for pest control'. This led to the formal establishment by ARS of the BCDC in October 1982. Other recommendations relating to documentation were made at two subsequent USDA-sponsored biological control conferences (Battenfield, 1983; US Department of Agriculture, 1984).

Following several reorganizations at Beltsville, the BCDC is now located in the Insect Biocontrol Laboratory of the Plant Sciences Institute. Major goals of the BCDC remain the development of information delivery and documentation systems to provide biological and taxonomic data on arthropods, weeds, and other pests; on their endemic, introduced and foreign natural enemies; and other information helpful to scientists and administrators in the conduct of biological control research programs, particularly those involving natural enemy introductions. The planned programs of the BCDC were described in the articles by Knutson, Thompson and Carlson (1987) and Coulson (1988). However, following a reorganization at Beltsville and consequent loss of personnel from the BCDC in late 1985, many of these programs were curtailed. The remaining programs of the BCDC that concern documentation of introductions of natural enemies and the computerized *Releases of Beneficial Organisms in the United States and Territories* (ROBO) database are described later in this paper.

Publications resulting from use of data from the files in the Center include rosters of North American biological control workers (included in Coulson and Hagan, 1986) and descriptions of USDA natural enemy introduction programs targeting alligatorweed (Coulson, 1977), gypsy moth (Coulson *et al.*, 1986, and sections of Doane and McManus, 1981), and *Lygus* and other plant bugs (Coulson, 1987). Other examples included in the list of references

to this paper concern a compilation of natural enemies of thistles (Batra *et al.*, 1981) and a record of the USA–USSR exchange of natural enemies program (Coulson, 1981).

It immediately became apparent, in working with the BCDC files, that many of the natural enemy importation and release records available in them were not in the compilation edited by Clausen (1978), correctly noted in the preface as a review only of *published* literature. The absence of published records of many importations and releases is often bemoaned in recent biological control publications (e.g. Greathead, 1986). Also quickly noted was the haphazard manner in which such records were kept. Therefore, efforts in the BCDC quickly concentrated on (1) making the unpublished information from the past more readily available through computerization and otherwise (e.g. as in the above-mentioned publications), and (2) improvement of the process of accumulation from all sources of importation and release records for the United States.

Good documentation involves careful record-keeping, retention of voucher specimens, and timely publication. The importance of voucher specimens to biological research has been stressed in many publications, most recently by Knutson (1984). The importance of timely publication of the results of biological control importation programs needs little comment. Concerning record-keeping, biological control scientists are not in general agreement as to whether a uniform method can, or should, be achieved, and a few remain to be convinced of the importance of maintaining careful records.

Reasons for good documentation/record-keeping

Classical biological control programs could be improved by more careful record-keeping, often lacking in the past, and by making the information readily available. The search for exotic organisms and their importation and release for biological control of pests provides not only an excellent opportunity, but also an obligation, to collect and store the maximum amount possible of information of current and future value to basic and applied research. There are three general groups of potential beneficiaries of such carefully prepared information, as discussed in this section.

Biological control practitioners and ecologists

This group includes research scientists, non-research 'implementers' of biological control, and program administrators. Regarding this group, it is useful to quote a short section from the preface of the world review by Clausen (1978):

> The movement of beneficial species from one country to another has now reached such proportions that it is difficult, if not impossible, to determine *from published records* [my italics] just what species have been colonized in new areas and what results have been attained. A reliable record of what beneficial species have been colonized, together with information on whether or not the species became established, is essential to the intelligent planning of future work of this nature. It is fully as important to have a record of failures as well as successes in this connection.

The value of such comprehensive compilations of past biological control importation programs as provided by Clausen (1956, 1978), and of the detailed historical information available in the BCDC, is often overlooked or ignored by present-day agricultural scientists and administrators. James Billington, US Librarian of Congress, commenting on the continued value of books in regard to present-day computerized technology, is quoted (Weeks, 1991) as reasserting the values of history, of memory:

> That's why... we talk about memory and imagination. You don't have any imagination without memory... And we're losing our memory. This [Washington] is a very present-minded city, and we have an extremely present-minded agenda, and there's a kind of dynamism of that that's attractive and should not be.

The same can be said about current 'high-tech' pest control programs in which historical summaries or recognition of past biological control efforts seem of little importance or relevance to some scientists and administrators, as does the information available in the BCDC, which has been noted to possess one of the last remaining corporate memories of the Agricultural Research Service.

Planning of classical biological control research programs benefits greatly from comprehensive information on what species of natural enemies are available for use against specific target pests, what species were previously imported, where they were collected and released, what their hosts were, where they were established, spread or recolonized, and where they currently or recently were laboratory cultured. Also important are names of individuals who conducted such importations, releases, and recolonizations, who cultured the material, or who provided the taxonomic determinations, and a record of any changed identifications involving descriptions of new species, synonymy, and new generic combinations. Much of this kind of information on past USDA classical biological control programs is available in the BCDC for use by ARS and other scientists.

Nevertheless, as already noted, much of this kind of information unfortunately remains unpublished, especially in cases where the importation program was considered a failure (Schroeder and Goeden, 1986), but also quite often when the program was curtailed for other reasons, e.g. when the scientist or graduate student conducting it moved on to another project, another location, or another research speciality, without a successor to continue the program. In these cases, exotic natural enemies may be found many years later to be established, i.e. 'naturalized', in areas of the United States, and precise information on their origins and releases may then be unavailable.

Careful documentation of the introduction, establishment, and spread of new organisms in the United States by biological control scientists is good science and an obligation of a good scientist. For the most part, biological control scientists do keep good records, although some may have reservations as to the timing and degree to which those records should be made available to others. Good documentation is, of course, important not only in planning future programs, but also in evaluating the results of

past programs, sometimes many years after the project was completed or otherwise curtailed.

Biological control practitioners are applied ecologists and the information they generate that is essential to the successful conduct of their research may be of considerable interest to theoretical ecologists. The results of applied ecology programs are useful to studies of species invasions, predation, competition, speciation and other basic ecological phenomena. The importance of documenting collections and introductions of organisms in regard to the recent interest in biodiversity and faunal surveys by both ecologists and taxonomists was noted in the introduction to this paper.

Animal and plant taxonomists

The BCDC has been queried by taxonomists of the ARS Systematic Entomology Laboratory (SEL) and elsewhere, who had received for identification specimens collected in the United States of species of natural enemies known or suspected to be of foreign origin, but for which no published information on their US introduction was known. Unpublished records in the BCDC files often have provided information on the introduction and origin of such material.

In addition, SEL taxonomists receive for identification specimens collected overseas of natural enemy species that had been imported and released in the United States, sometimes in great numbers, in previous importation programs, but for which no published records existed and of which only a few (or sometimes no) specimens were available for comparison in the US National Insect Collection.

These were two of the main reasons for development by the BCDC of the computerized *Releases of Beneficial Organisms in the United States and Territories* or ROBO program, and for the proposed US National Voucher Collection of Introduced Beneficial Arthropods. The formation of the latter was announced in 1980 (Knutson, 1981), but plans for this collection, which involved a reciprocal exchange of voucher specimens with the Canadian National Insect Collection, were curtailed owing to loss of technical support in the Center. Taxonomists working with the US National Collection of Insects in the US National Museum of Natural History and with other *national* collections should automatically be provided with information on the field release and recolonization of exotic invertebrates that represent potential or actual new additions to the United States fauna, or significant extensions of range. Specimens representing these species, i.e. vouchers, also should be deposited in the US National Museum or other national collections, such as the USDA collection of nematodes in the ARS Nematology Laboratory at Beltsville. Deposition of voucher specimens of all introduced biological control agents in national collections is required by regulation in Australia (E.S. Delfosse, personal communication, 1991). Voucher specimens should also be deposited in collections located at the quarantine facility, university, or other locations where the introductions and research have been conducted, if there are provisions for long-term proper specimen curation for these collections.

Taxonomists are usually the beneficiary of more comprehensive information accompanying specimens that they receive from biological control workers than is usually available with specimens received from other sources. This includes host/parasite information as well as other biological, geographical and ecological collection data. This is most important because many of the insect and weed natural enemy species discovered and introduced by biological control workers are new to science; subsequent descriptions of these species can be accompanied by information not always available for other new species.

Not only SEL taxonomists serve as a source of identifications in the United States, of course. The same needs and benefits also accrue to other taxonomists of invertebrates and, perhaps to a lesser degree, plant taxonomists, in the United States, Canada and elsewhere.

Regulatory agencies and the general public

There is increasing interest in biological control by regulatory agencies, by environmental groups, and by other segments of the general public, particularly regarding the introduction of exotic species into the United States and other countries. Biological control scientists are rightly concerned that regulations may be developed that will adversely affect classical biological control, which has proved to be a successful, environmentally sound, and cost-effective form of pest control. A system for freely providing a record of biological control introductions, along with descriptions of the precautions being taken in making those introductions (e.g. in the form of 'guidelines'), may help to circumvent the development of such strict regulations.

Quarantine and other US federal and state regulatory officials and the public have a right to timely information on what exotic species of plants or animals are being introduced into the United States. A system to record and publish the introduction of exotic *plant* germplasm has long existed, which now is part of USDA's Germplasm Resources Information Network (GRIN) program (Perry, Stoner and Mowder, 1988). The most recent compilation from GRIN reports plant importations during calendar year 1990 (US Department of Agriculture, 1991). The ROBO program, discussed later in this paper, was developed to record and publish details on the introduction into the United States of other exotic, beneficial germplasm, i.e. biological control organisms and pollinators. A similar database and annual publication series for introductions of natural enemies into Canada have existed since the 1930s, the last compilation covering 1989 introductions (Sarazin, 1990). The Canadians have also been able to provide comprehensive and timely descriptions of their biological control programs over the years (McLeod, McGugan and Coppel, 1962; Commonwealth Agricultural Bureaux, 1971; Kelleher and Hulme, 1984).

The need for such annual and other periodic compilations and reviews of introduced organisms in the United States is particularly critical now. The US National

Environmental Policy Act of 1969 requires that all federal agencies consider the environmental impact of major actions that may significantly affect the quality of the human environment in the United States. USDA agencies currently interpret this to mean that, with certain exceptions, a formal Environmental Assessment (EA) is required for the *initial* field release of exotic biological control agents in the United States. That is, an environmental risk analysis must be applied in such actions by ARS (Agricultural Research Service, 1986), and for the issuance of federal permits for such releases by USDA's regulatory agency, the Animal and Plant Health Inspection Service (APHIS). In view of this, a compilation of organisms previously released in the United States will be of benefit to state and federal regulatory agencies as well as to the biological control community.

Information on the introduction of exotic organisms should not be treated by biological control scientists as privileged information; doing so may represent an ultimate danger to biological control in the United States and elsewhere under the present-day climate of public environmental concern. Regular and timely provision of information on releases of exotic species can avoid potential problems in the future. The amount of information to be provided and the degree of timeliness present some problems, as discussed later in this paper.

Methods of record-keeping for classical biological control in the United States

Documentation systems for invertebrate biological control agents

There are basically three current types of record-keeping for US programs involving introduction of invertebrate natural enemies of arthropod pests and weeds: the Hawaiian, University of California and USDA systems. The biological control section of the Hawaiian Department of Agriculture produces excellent monthly reports of their importation and release activities; these unpublished reports are on file in the BCDC. Lists of the species released in Hawaii have been published periodically in the *Proceedings of the Hawaiian Entomological Society*.

The University of California record-keeping system was described by Fisher (1964). The basic and main record form involved is the Sender's and Receiver's (S & R) Report. The shipper/sender of the material completes one side of the card [5 × 8 inches (≈ 127 × 203 mm)] to include abbreviated collection and shipment data; the receiver adds a chronologically assigned S & R number, and completes the other side of the card in quarantine, with a report of the condition of the shipment and a record of natural enemy emergence. Details of collection, emergence and identification are obtained from ancillary forms or notes. One S & R Report can include several shipments, from several locations, and from several hosts, in which case each is referred to by a subnumber of the basic S & R Record number. Thus, each natural enemy species received can be referred to by a specific S & R number, which, regardless of the subsequent history of the material, i.e. its subsequent culture, etc., traces the material back to its origin. The University produces semi-annual reports of the material introduced and propagated in quarantine, and of the field release in California of the introduced natural enemies. These unpublished reports are sent to appropriate offices of the University, of the California Department of Food and Agriculture, and of the USDA, including the BCDC.

The Californian and Hawaiian systems are simple ones and excellent for units with relatively small numbers of scientists intimately involved, often from collection to release, in the specific biological control programs documented. However, they work less well with regard to trans-shipment of introduced material to other workers, often located out-of-state or overseas, who are less intimately involved in the programs, and where more detailed information is often helpful. Such trans-shipments are quite often involved in biological control importation programs of the ARS, and recently also of APHIS, in which natural enemies collected by ARS or other scientists overseas are trans-shipped from quarantine in the United States to a number of federal, university and state workers in regional or nationwide biological control programs.

To improve the process of preparation and accumulation of importation and release records for ARS programs, two forms were designed, with the help of ARS and other biological control workers, and were placed into operation by ARS units by the mid-1970s. These ARS forms (ARS-441 and -442) for the first time provided a uniform system for documenting ARS biological control introductions. An excellent computerized system, BIRLDATA, based on those forms, was developed by the ARS Beneficial Insects Research Laboratory in Delaware, to document the importation, trans-shipment and release of materials made by that facility. This laboratory is the principal ARS quarantine facility for importation of parasites and predators of arthropod pests. The BIRLDATA system as described by Dysart (1981) has since had many improvements. Dysart expressed concern over the lack of compatibility among US biological control documentation systems, and doubted that a comprehensive, truly national system could be developed.

The two ARS forms were revised in 1984 as a result of responses to a lengthy 1982 questionnaire sent by the BCDC to numerous federal, state and university biological control personnel during development of the ROBO program described below. These revised USDA (AD) shipment record forms are illustrated by Knutson *et al.* (1987).

One form, the AD-941, is used for recording collection and culture data for material shipped from or to foreign sources; a booklet of an abbreviated version of this form was developed for use by collectors in the field. The second form, the AD-942, is used for providing source and culture information for material consigned, trans-shipped, or field released from quarantine. A third form, the AD-943, was designed in 1984 for non-quarantine use in recording recolonizations from established domestic populations and releases from non-quarantine cultures of introduced natural enemies.

These forms were designed (1) to include as much relevant data as possible, some of which are relegated to ancillary forms in other recording systems; (2) to facilitate communication between the shipper and recipient of the material, to include original collection/culture data from the former, and feedback information from the latter; and (3) to foster the regular retention of 'representative specimens', i.e. vouchers, of the natural enemy, and sometimes of the host/prey.

The use of these forms is included in the draft ARS guidelines for the introduction and release of invertebrate biological control agents in the United States, which were reviewed and discussed by many federal, state and university scientists and regulatory officials at, during, and subsequent to the ARS Workshop on 'Biological Control Quarantine: Needs and Procedures', held in Baltimore, Maryland, in January, 1991. These draft guidelines describe proposed procedures for ARS scientists for introduction and release in the United States of arthropod natural enemies of arthropods, arthropod-parasitic nematodes, and invertebrate natural enemies of weeds (Coulson *et al.*, 1991).

As the number of biological control quarantine facilities and personnel has expanded in the United States since the 1970s, the BCDC has promoted the regular, voluntary use of the USDA record forms by *all* US biological control locations to provide a uniform, nationwide documentation system. This has been partially successful to date; a number of other federal, university and state facilities now use one or more of the forms as a matter of course. Others use variants of the University of California system, or systems specifically designed for their own programs.

Efforts are continuing to promote the common use of at least the form recording the consignment or release of exotic material from quarantine, the AD-942, by all quarantine facilities throughout the United States. A similar data form may be useful in other countries. An explanation of the use of the AD-942 form (*Figure 1*) is provided here.

Form AD-942: biological shipment record – quarantine facility. Each form is a set of four copies and is provided with detailed instructions for its use. A brief description of the information to be supplied for some of the blocks of the form is given below. Copies of this and other forms mentioned in this paper are available from the BCDC. One AD-942 form is to be used for each *shipment* (or series of like shipments) from a quarantine facility, or for each *species* consigned to non-quarantine areas of the facility, or to non-quarantine status within quarantine, during a single year.

Blocks 1–2, 4–5, 7–9, 11, 13–14, and 18: Self-explanatory.

Block 3: Identifies the quarantine facility, year, and chronological shipment/consignment number.

Block 6: Useful for recipients of material; provides information on length of time since egg/larval/adult stage was entered. 'Shipped directly' means trans-shipped or consigned in the same stage as received in quarantine.

Block 10: Can include material from several collection sites (see Block 12).

Block 12: Place to record the single or several foreign source file numbers (from AD-941 forms and/or S & R Record forms or other records).

Blocks 16–17: Indicates whether material has been cultured, on what host/prey, where, and for how long.

Block 19: Name and affiliation of person to whom material was consigned or shipped from quarantine; if material was field-released *directly* from quarantine, information is to be provided in Section III.

Blocks 21 and 26: Can be a range of dates within a single year; useful for consignment of material from a quarantine culture or of material recovered from a foreign shipment over a period of time (within a single year).

Blocks 22 and 33: Call for noting 'representative specimens' (vouchers) retained by quarantine and by the recipient of the material.

Block 34(A): Recipient completes Section III upon release of some or all of the material received from quarantine. *(B and C)*: When culture is intended, recipient completes block 35; all subsequent releases or shipments of material from successful cultures, generally requiring separate records (such as the AD-943 form), are referenced to the Quarantine File No. (block 3) as source of the culture; original source file numbers are readily obtainable by reference to the Quarantine File No., or can be included (e.g. S & R nos.) in the subsequent shipment/release records.

Section III (release data): Self-explanatory.

Use of the USDA form requires more attention than in other systems in providing fairly precise information on numbers and stages of the species being consigned to or released from quarantine, and on the culture history of that material. Such information may have a bearing on the interpretation of the success or failure of cultures or field establishments, and may indicate whether contamination or genetic changes of material in long-term culture may be involved.

Documentation system for microbial biological control agents

There is increasing interest in the United States and elsewhere in the introduction and release of exotic *microbial* organisms for control of arthropods, weeds, plant nematodes and plant pathogens. To date, micro-organisms have been relatively freely exchanged between research scientists worldwide, with little or no published documentation. Documentation needs for microbial organisms differ considerably from those for invertebrates because of basic differences in the biologies of the organisms, research methodologies and regulatory procedures. Over the past several years, discussions were conducted between the BCDC and federal and university arthropod and plant pathologists on the question of documenting the importation of exotic microbial organisms into the United States and their field release. A survey of arthropod pathologists indicated general agreement that such a documentation system was needed (Coulson and Soper, 1989); similar agreement was expressed by plant pathol-

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BIOLOGICAL SHIPMENT RECORD – QUARANTINE FACILITY

(Shipment/Consignment from Quarantine)

45. FINAL DETERMINATION - Gen., sp., subsp., auth. — a ☐ M ☐ NC; b ☐ M ☐ NC
46. V.S. (use files) — a ☐; b ☐

SECTION I – REPORT OF MATERIAL SHIPPED, CONSIGNED or RELEASED

1. FROM *(Quarantine facility - name and address)*
2. ORGANISM SHIPPED - A. Gen., sp., subsp., auth.
   B. Order: Family
   C. Determined by *(names & affiliations)*
3. QUARANTINE FILE NO.
4. TYPE OF ORGANISM - explain MI & OT in blk. 20
   ☐ PArasite ☐ WEed feeder ☐ PRedator ☐ POllinator ☐ MIcrobial ☐ OTher
5. NOS. & STAGES SHIPPED *(see codes)* — Est / Est / Est — TOTAL:
6. DATES TRANSFORMED TO STAGES SHIPPED *(month, day, year)* — ☐ Shipped directly ☐ Emerged in Quarantine
7. MATING OBSERVED — ☐ Yes ____% ☐ No
8. HOST/PREY/PEST MATERIAL PRESENT — ☐ Beneficial with host/prey ☐ Host/prey/pest only ☐ None
9. DATES ORIGINALLY FIELD COLLECTED *(m,d,y)*
10. LOCATION - Country & Province/State of Origin
11. ORIGINAL COLLECTORS *(names & affiliations)*
12. FOREIGN/OVERSEAS SOURCE FILE NOS.
16. LAB CULTURED (F_1 +) — ☐ Overseas ☐ No ☐ In Quarantine ____ *(number of generations)*
13. ORIGINAL HOST/PREY - Gen., sp. *(or other food source)*
14. STAGE/PART OF HOST/PREY ATTACKED
15. ORIGINAL FOOD SOURCE OF HOST/PREY
17. LAB HOST/PREY - Gen., sp. *(if different from blk. 13)*
18. INTENDED HOST/PREY - Gen., sp. *(if different from blk. 13)*
19. SHIPPED/CONSIGNED TO
20. REMARKS
21. DATE shipped/consigned *(m,d,y,)*
22. REPRESENTATIVE SPECIMENS RETAINED — Yes — number:
23. PACKING/HANDLING — ☐ Usual ☐ Other *(explain in blk. 20)*
24. SHIPPED VIA
25. SCREENED OR PACKAGED BY

SECTION II – REPORT OF RECEIPT AND INTENDED USE

26. DATE OF RECEIPT *(m,d,y)*
27. DATE OPENED *(m,d,y)*
28. CONDITION RECEIVED — A. Container — B. Contents
29. REPORTED OR EXAMINED BY

30. INVENTORY OF MATERIAL RECEIVED *(use codes)*

A. Number and stages received *(blk. 2)* Alive	Dead	B. Number Emerged *(stages)* Beneficials Alive	Dead	Host/Prey Alive	Dead
TOTALS E	E	E	E	E	E

31. OTHER SPECIES INCLUDED OR EMERGED

A. Order: Family and Genus, species, author, if known	B. Determined by *(name & affiliation)*	C. No. and Stages *(use codes)*

32. REMARKS
33. SPECIMENS FROM SHIPMENT RETAINED BY RECEIVER — ☐ Yes ____ *number* ☐ No
34. INTENDED USE — A. ☐ Immediate release *(complete Sec. III)* — Lab culture/study: B. ☐ Release intended; C. ☐ No release intended
35. INTENDED LAB HOST/PREY - Gen., sp.

SECTION III – REPORT OF RELEASE

	SITE 1	SITE 2	SITE 3
36. Types of release	☐ Field ☐ Greenhouse ☐ Cage ☐ Other:	☐ Field ☐ Greenhouse ☐ Cage ☐ Other:	☐ Field ☐ Greenhouse ☐ Cage ☐ Other:
37. Locations (State, County, nearest Town or physical feature, map coordinates) *(Use AD-942A for more details)*			
38. Number and stages released. *(see codes)*	Est	Est	Est
39. Dates of release *(m,d,y)*			
40. Target hosts/prey at release A. Primary - *Genus, species*			
B. Other - *Genus, species*			
C. Families			
41. Food (plant/animal/other) of target host/prey at release.			
42. Released by *(Name & affiliation)*			

43. REMARKS *(use AD-942A for more details)*
44. REPORTED BY — A. Name — B. Date *(m,d,y)*

Form AD-942 (10/83) — Part 1 - DOCUMENTATION CENTER COPY

Figure 1. Form AD-942: Biological Shipment Record – Quarantine Facility

ogists involved in weed control with exotic plant pathogens. There is much less agreement on this point among plant pathologists involved with microbial organisms for control of plant pathogens and nematodes; it is felt that these organisms present little likelihood of long-term field establishment and thus there is less need for detailed documentation of their introduction and field release.

Two draft forms have been developed by the BCDC in collaboration with arthropod and plant pathologists to record (1) the introduction (AD Form 944) and (2) the field release (AD Form 944A) of exotic microbial organisms for biological control purposes. The use of these forms is included in draft ARS guidelines for the introduction and release of microbial biological control agents in the United States, reviewed and discussed at the Baltimore Workshop. These proposed guidelines describe procedures for ARS scientists for introduction and release in the United States of exotic microbial natural enemies of arthropods and weeds, and of exotic microbial natural enemies and antagonists of plant pathogens and nematodes (Coulson *et al.*, 1991). The AD-944 and AD-944A forms are now undergoing final approval and will be printed and in operation for ARS scientists in 1992.

It should be noted that no efforts are planned to track commercial shipments of microbial pesticides or the *interstate* shipment of microbial organisms for research purposes; the intent of the ARS documentation system is to track only the *importation* of exotic microbial organisms for research purposes and their *field release* for establishment (which can involve documenting experimental field tests) in the United States.

The ROBO program and objections to detailed record-keeping

ROBO and other BCDC programs are briefly described in the paper by Knutson *et al.* (1987). ROBO is a computerized database program and periodic publication of data on 'Releases of Beneficial Organisms in the United States and Territories.' In accordance with several recommendations over the past 15 years as noted above, and as a major thrust of the BCDC, a database and publication series, similar to GRIN for exotic *plant* germplasm, was developed to record the introduction into the United States of other exotic, beneficial germplasm, biological control organisms and pollinators. The existence of the similar database and longstanding publication series for biological control introductions into Canada was noted above.

ROBO is currently based on the three USDA shipment/release record forms, and was designed to benefit the three groups of beneficiaries listed earlier. It was developed with the help of many biological control practitioners from throughout the United States and elsewhere who responded to a very detailed user survey questionnaire in 1982. The intent of the program is to provide a published record and searchable database of all releases of biological control organisms in the United States that represent potential extensions to the distributions of the organisms or the introduction of new strains or biotypes. That is, introductions of newly imported organisms and transfers of established exotic species into areas of the United States where they do not occur, are both recorded in the database and publications.

ROBO was originally designed to record introductions only in the continental United States, but the Center was quickly informed by Hawaiian colleagues that, as Hawaii was in fact part of the United States, it should not be excluded from the program. This caused some initial difficulties, but ROBO now addresses introductions not only in Hawaii, but also in US overseas territories (Puerto Rico, Virgin Islands, Guam, American Samoa and other Pacific territories). It also includes records of shipments of natural enemies from US facilities to foreign countries.

The ROBO publications also provide lists of the released organisms by taxonomic hierarchy, by host/prey against which they were released, and by state/territory in which they were released. The database can also be used to provide computerized annual reports, which are not meant for publication, on shipments made from or received by individual facilities, foreign and domestic, or received in individual states/territories, and individual shipment and release reports that provide collection, shipment and release data; several examples of Release Reports are illustrated by Coulson, Carrell and Vincent (1988).

The first of the planned annual ROBO publications, beginning with 1981 data, has been issued (Coulson *et al.*, 1988), and copies are available from the BCDC. To illustrate the amount of data included, the publication lists releases and recolonizations in 1981 alone involving $> 13.5 \times 10^6$ individuals of 145 species of insect and mite parasites and predators against 84 insect and mite pests, and $> 1.5 \times 10^6$ individuals of 20 species of natural enemies of 18 species of weeds. Releases of six species of pollinators and other beneficial invertebrates are also recorded.

Although records of the introduction and release of exotic microbial organisms are included in the current ROBO program, a new subprogram will be developed based upon the new documentation forms (AD-944 and AD-944A) for microbial organisms; it is intended that records of field releases of exotic microbial organisms will continue to be included in the ROBO publications.

Entry of 1982 records into the ROBO database has been completed, and these data will be published early in 1992. Entry of 1983 records is under way. Entry of subsequent records will not be as difficult, because the new record forms became operational in 1984.

Objections to ROBO and associated detailed record-keeping

Data entry into the ROBO database over the past few years required frequent contacts with scientists involved in classical biological control. Although most have been fully supportive, some have expressed concerns over the program; others, fortunately very few, have simply ignored it. The amount of information provided, degree of timeliness in providing it, and publication of that information are items of concern among some biological control researchers and university professors, whose responsibilities

include publication of their research findings. The concerns are for the most part valid and are addressed here.

The first concern is the amount of clerical time required to provide the details requested for the ROBO database, some of which some scientists feel are irrelevant. The USDA record forms upon which ROBO is based are indeed more detailed than, for example, the University of California forms. For the first few years of data entry, the USDA forms were not in use, and in some cases still are not. In those cases, the Center has utilized data available from the prevailing documentation systems. However, in order to 'debug' the ROBO computer program, an effort was made to enter as many details as possible; often such details were not available. The amount of data to be provided for ROBO certainly depends upon the provider. The details requested, as included on the USDA forms, are the result of comments received from the many scientists surveyed in 1982 during the development of the program. It is hoped that the few scientists objecting to those details (primarily those who did not respond to the 1982 'user survey') will eventually recognize the benefits of the program as enumerated above and thus of spending the time to provide details.

Another objection to the ROBO program also concerns the amount of detail that it entails and the use to which that information is put. That is, there has been concern expressed by some research scientists and professors over the effect of the publication or other availability of their collection and release data in ROBO on the later publication of their research results in scientific journals. This concern has been for the most part successfully countered for many co-operating scientists by (1) the safeguards built into the ROBO program to prevent the accessibility of data until permission is given by the data provider, (2) by the means provided for giving credit to the releaser or project leader for the release information in the ROBO publication, and (3) the fact that the amount of detail actually published or otherwise available is really very small, as illustrated by Coulson *et al.* (1988). Furthermore, data publication or access is currently delayed by as much as 9 years after importation or release; it is hoped that eventually this delay will be only 2–4 years.

More importantly, the ROBO publication concerns only the release and recolonization of organisms. Although, by recording recolonizations, some information on establishments and spread can be obtained from the database, most data on establishments, and all on the impacts of the establishments, are excluded from the ROBO program. This leaves publication of this important information and all other details to those responsible for the research program. A published record of releases and recolonizations provided by ROBO makes that information available in cases in which the results of a research program are *never* published, which, as previously noted, has occurred all too frequently.

Another concern involves one use to which information in the ROBO database may be put. A few scientists are concerned over published analyses of various aspects of classical biological control programs based on such compendia as the literature review edited by Clausen (1978), and suggest that ROBO would provide additional resources for such analyses. This may be true; nevertheless, such analyses will continue to be made with or without ROBO, particularly in view of the plans of the International Institute of Biological Control to produce another record of biological control programs from their building databases, based primarily on published information (Greathead, 1986). ROBO adds to the published record much data that might not otherwise be published, so that such analyses, regardless of their ultimate value, can be based on much more complete information than is currently the case. The presence (or absence) of details in the ROBO database also provides the opportunity to distinguish the more meaningful, scientifically based releases from those less so, and to make more appropriate assessments based on those details.

A small workshop is being planned to address these and other concerns expressed by biological control workers about the ROBO program, after which the data requirements for this program may be revised.

Future of ROBO and the ARS Biological Control Documentation Center

Unfortunately, biological control documentation is currently low in priority in the competition for scarce research resources within the ARS. As a result, some support personnel lost by the BCDC in 1985 have not yet been replaced. If adequate support for biological control documentation can be restored, the annual ROBO publications can continue, and the gap between the date of the importation and release records and their publication can be narrowed, making the reports more timely and useful, rather than simply archival documents.

At the same time, attention can then be devoted to the second major aim of the Documentation Center, the computerization of the many records in the Center's files of past importations and releases in the United States. The first goal is to enter into the ROBO database records from 1980 back to 1968, the cut-off date for records in Clausen (1978). The second goal is to add records dating back through 1934, the earliest date for which good records are available in the Center's files. Importations made by the USDA from 1934 to 1949 have already been compiled, but have not yet been entered into ROBO. Records available from the BIRLDATA database will be helpful additions to the reports and other materials available in the Documentation Center with regard to data for subsequent years. Some early University of California and Hawaii Department of Agriculture records are also available for data entry. With completion of such computerization, the full benefit of the ROBO database could be realized.

Biological control documentation in other parts of the world

The bulk of the comments in this paper have related so far to the situation in the United States. A few specific

comments on biological control documentation in other parts of the world are appropriate. The Food and Agriculture Organization (FAO) of the United Nations is preparing an international code of conduct for the use of biological control agents, which undoubtedly will contain reference to the need for proper documentation of the movement and introduction of agents from one country to another.

The International Institute of Biological Control (IIBC) provides contract services to countries throughout the world on research on natural enemies of arthropod and weed pests, and on their collection and distribution to other countries. The shipment record form currently utilized by the IIBC with its natural enemy shipments provides only the barest of information on the collection origin and culture history of the material being shipped; additional details are provided in correspondence between the shipper and recipient and by other means, including unpublished project reports. The shipments are also recorded in the annual reports of IIBC. IIBC shipment record forms could be improved to provide a more complete and lasting record of the shipments made by this international agency for the benefit of the records of the recipient countries.

Many countries have shipment record forms of some type that provide information on shipments of live biological material sent or received. In an annex to the preliminary document prepared by Way (1990) for the FAO to consider in relation to an international code of conduct, it was noted that the Soviet Union utilized a form similar to the USDA AD-941 form to record its incoming shipments of biological control material. There are very useful published records of classical biological control programs in various parts of the world, in addition to those noted above for the United States and Canada. These include the excellent series of publications by the IIBC, reviewing programs in various regions of the world (e.g. Greathead, 1971, 1976; Rao *et al.*, 1971; and Cock, 1985), reviews prepared for individual countries, e.g. that by Wilson (1960) for Australia and those by Cameron *et al.* (1987, 1989) for New Zealand, and the excellent compilation of programs for biological control of weeds throughout the world by Julien (1987)

As noted in the introduction and throughout this paper, the need to prepare more detailed records of the movement of live organisms from one part of the world to another is becoming increasingly important. It is hoped that biological control workers and organizations throughout the world will recognize this need, and work towards better documentation of their activities. It seems doubtful that a uniform international system for such documentation can be developed, but perhaps the USDA and ROBO systems can provide an example of the types of information needed, and an example of some pitfalls that might be avoided in implementation of a documentation system.

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References

Agricultural Research Service (1986) Final regulations for implementing National Environmental Policy Act (NEPA). *Fed. Reg.* **51** (186), 34190–34192

Batra, S. W. T., Coulson, J. R., Dunn, P. H. and Boldt, P. E. (1981) *Insects and Fungi associated with* Carduus *Thistles. USDA Tech. Bull. 1616*, USDA, Washington, DC. 100 pp

Battenfield, S. L. (Ed.) (1983) *Proceedings of the National Interdisciplinary Biological Control Conference, February 15–17, 1983, Las Vegas, Nevada.* US Department of Agriculture, Cooperative State Research Service, Washington. 107 pp

Cameron, P. J., Hill, R. J., Valentine, E. W. and Thomas, W. P. (1987) Invertebrates imported into New Zealand for biological control of invertebrate pests and weeds, for pollination, and for dung dispersal, from 1874 to 1985. *DSIR Bull. 242*, Department of Scientific and Industrial Research, Wellington. 51 pp

Cameron, P. J., Hill, R. J., Bain, J. and Thomas, W. P. (Eds) (1989) *A Review of Biological Control of Invertebrate Pests and Weeds in New Zealand 1874 to 1987. CAB Int. Inst. Biol Control Tech. Commun. 10*, CAB IIBC, Ascot. 424 pp

Clausen, C. P. (1956) *Biological Control of Insect Pests in the Continental United States. USDA Tech. Bull. 1139*, USDA, Washington DC. 151 pp

Clausen, C. P. (Ed.) (1978) *Introduced Parasites and Predators of Arthropod Pests and Weeds: A World Review. USDA Agric. Handbk 480*, USDA, Washington DC. 545 pp

Cock, M. J. W. (Ed.) (1985) *A Review of Biological Control of Pests in the Commonwealth Caribbean and Bermuda up to 1982. Commonw. Inst. Biol. Control Tech. Commun. 9*, CAB, Slough. 218 pp

Commonwealth Agricultural Bureaux (1971) *Biological Control programs Against Insects and Weeds in Canada 1958–1968. Commonw. Inst. Biol. Control Tech. Commun. 4*, CAB, Slough. 266 pp

Coulson, J. R. (1977) *Biological Control of Alligatorweed, 1959–1972: A Review and Evaluation. USDA Tech. Bull. 1547*, USDA, Washington, DC. 98 pp

Coulson, J. R. (1981) The Soviet–American environmental agreement and exchange of beneficial organisms, 1972–1979. In: *Proceedings of the Joint American–Soviet Conference on Use of Beneficial Organisms in the Control of Crop Pests* (Ed. by J. R. Coulson) pp. 1–11, Entomological Society of America, College Park, Maryland

Coulson, J. R. (1987) Studies on the biological control of plant bugs (Heteroptera: Miridae): A history, 1961–1983. In: *Economic Importance and Biological Control of* Lygus *and* Adelphocoris *in North America. USDA, ARS, ARS-64* (Ed. by R. C. Hedlund and H. M. Graham) pp. 1–12, USDA, Washington, DC

Coulson, J. R. (1988) Biological control documentation center, Agricultural Research Service. In: *ARS National Biological Control Program, Proceedings of Workshop on Research Priorities* (Ed. by E. G. King, J. R. Coulson and R. J. Coleman) pp. 23–26, USDA, ARS, Washington, DC

Coulson, J. R. and Hagan, J. H. (Compilers) (1986) *Biological Control Information Document, September 1985*, USDA, ARS, ARS Biological Control Documentation Center, Washington. 95 pp

Coulson, J. R. and Soper, R. S. (1989) Protocols for the introduction of biological control agents in the U.S. In: *Plant Protection and Quarantine, Volume III Special Topics* (Ed. by R. P. Kahn) pp. 1–35, CRC Press, Inc., Boca Raton, Florida

Coulson, J. R., Carrell, A. and Vincent, D. L. (compilers) (1988) *Releases of Beneficial Organisms in the United States and Territories – 1981. USDA Misc. Pub. 1464*, USDA, Washington, DC. 324 pp

Coulson, J. R., Soper, R. S. and Williams, D. W. (Eds) (1991) *Proceedings of the USDA–ARS Workshop on Biological Control Quarantine: Needs and Procedures (14–17 January 1991, Baltimore, Maryland)*, USDA, ARS, Washington, DC. 336 pp

Coulson, J. R., Fuester, R. W., Schaefer, P. W., Ertle, L. R., Kelleher, J. S. and Rhoads, L. D. (1986) Exploration for and importation of natural enemies of the gypsy moth, *Lymantria dispar* (L.) (Lepidoptera: Lymantriidae), in North America: an update. *Proc. Entomol. Soc. Washington* **88**, 461–475

DeBach, P. and Schlinger, E. I. (Eds) (1964) *Biological Control of Insect Pests and Weeds*, Reinhold, New York. 844 pp

Doane, C. C. and McManus, M. L. (Eds) (1981) *The Gypsy Moth: Research Toward Integrated Pest Management. USDA Tech. Bull. 1584*, USDA, Washington, DC. 757 pp.

Dowden, P. B. (1962) *Parasites and Predators of Forest Insects Liberated in the United States Through 1960. USDA Agric. Handbk 226*, USDA, Washington, DC. 70 pp

Dysart, R. J. (1981) A new computer data bank for introduction and release of beneficial organisms. In: *Beltsville Symposia in Agricultural Research 5: Biological Control in Crop Production* (Ed. by G. C. Papavizas) pp. 121–128, Granada, London

Fisher, T. W. (1964) Quarantine handling of entomophagous insects. In: *Biological Control of Insect Pests and Weeds* (Ed. by P. DeBach and E. I. Schlinger) pp. 305–327. Reinhold, New York

Fisher, T. W. and Andres, L. A. (1992) Quarantine: concepts, facilities, procedures. In: *Principles and Application of Biological Control* (Ed. by T. W. Fisher *et al.*) Ch. 15, University of California Press, in press

Greathead, D. J. (1971) A review of biological control in the Ethiopian Region. *Commonw. Inst. Biol. Control Tech. Commun. 5*, CAB, Slough. 162 pp

Greathead, D. J. (Ed.) (1976) A review of biological control in western and southern Europe. *Commonw. Inst. Biol. Control Tech. Commun. 7*, CAB, Slough. 182 pp

Greathead, D. J. (1986) Parasitoids in classical biological control. In: *Insect Parasitoids* (Ed. by J. Waage and D. Greathead) pp. 290–318, Academic Press, Inc., London

Howarth, F. G. (1991) Environmental impacts of classical biological control. In: *Annual Review of Entomology, Vol. 36* (Ed. by T. E. Mittler, F. J. Radovsky and V. H. Resh) pp. 485–509, Annual Reviews Inc., Palo Alto, California

Julien, M. H. (Ed.) (1987) *Biological Control of Weeds: A World Catalogue of Agents and their Target Weeds*, 2nd edn, CAB IIBC, Ascot. 150 pp

Kelleher, J. S. and Hulme, M. A. (Eds) (1984) *Biological Control programs against Insects and Weeds in Canada 1969–1980*, CAB, Slough. 410 pp

Kim, K. C. and Knutson, L. (Eds) (1986) *Foundations for a National Biological Survey*, Association of Systematics Collections, Lawrence, Kansas. 215 pp

Knutson, L. (1981) Symbiosis of biosystematics and biological control. In: *Beltsville Symposia in Agricultural Research 5: Biological Control in Crop Production* (Ed. by G. C. Papavizas) pp. 61–78, Granada, London

Knutson, L. (1984) Voucher material in entomology: a status report. *Bull. Entomol. Soc. Am.* **30** (4), 8–11

Knutson, L., Thompson, F. C. and Carlson, R. W. (1987) Biosystematic and biological control information systems in entomology. In: *Agricultural Zoology Reviews, Vol. 2* (Ed. by G. E. Russell) pp. 361–412, Intercept, Wimborne, Dorset

Lancaster, J. (1991) Protecting a wealth of species: bill aims at cataloguing, conserving a wider range of organisms. *Washington Post* 24 May 1991, A21

McLeod, J. H., McGugan, B. M. and Coppel, H. C. (1962) *A Review of the Biological Control Attempts Against Insects and Weeds in Canada. Commonw. Inst. Biol. Control Tech. Commun. 2*, CAB, Farnham Royal. 216 pp

Perry, M. C., Stoner, A. K. and Mowder, J. D. (1988) A plant germplasm information management system: Germplasm Resources Information Network. *Hort. Sci.* **23**, 57–60

Rao, V. P., Ghani, M. A., Sankaran, T. and Mathur, K. C. (1971) *A Review of the Biological Control of Pests in South-East Asia and the Pacific Region. Commonw. Inst. Biol. Control Tech. Commun. 6*, CAB, Slough. 149 pp

Sarazin, M. J. (Compiler) (1990) *Insect Liberations in Canada, Parasites and Predators 1989*, Agriculture Canada, Ottawa. 47 pp

Schroeder, D. and Goeden, R. D. (1986) The search for arthropod natural enemies of introduced weeds for biological control – in theory and practice. *Biocontrol News Info.* **7**, 147–155

US Department of Agriculture (1978) *Biological Agents for Pest Control – Status and Prospects*, USDA, Washington, DC. 138 pp

US Department of Agriculture (1984) *Research Planning Conference on Biological Control, March 20–22, 1984* [Laurel, Maryland], USDA, ARS, Washington, DC. 473 pp

US Department of Agriculture (1991) *Plant Inventory No. 199, Parts I and II.* USDA, ARS, Washington, DC. Pt. I, 684 pp; Pt. II, 691 pp

Wapshere, A. J., Delfosse, E. S. and Cullen, J. M. (1989) Recent developments in biological control of weeds. *Crop Prot.* **8**, 227–250

Way, M. J. (1990) *Biological Control Introductions: A Review and Justification of the Need for a Code of Conduct with Recommended Code for Consideration at a FAO Expert Consultation*, Imperial College of Science and Medicine, Ascot, unpublished document. 33 pp. and 18 annexes

Weeks, L. (1991) Endangered species? The Library of Congress and the future of the book. *Washington Post Mag.* 26 May 1991, 11–17, 27–31

Wilson, F. (1960) *A Review of the Biological Control of Insects and Weeds in Australia and Australian New Guinea. Commonw. Inst. Biol. Control, Tech. Commun. 1*, CAB, Farnham Royal. 102 pp